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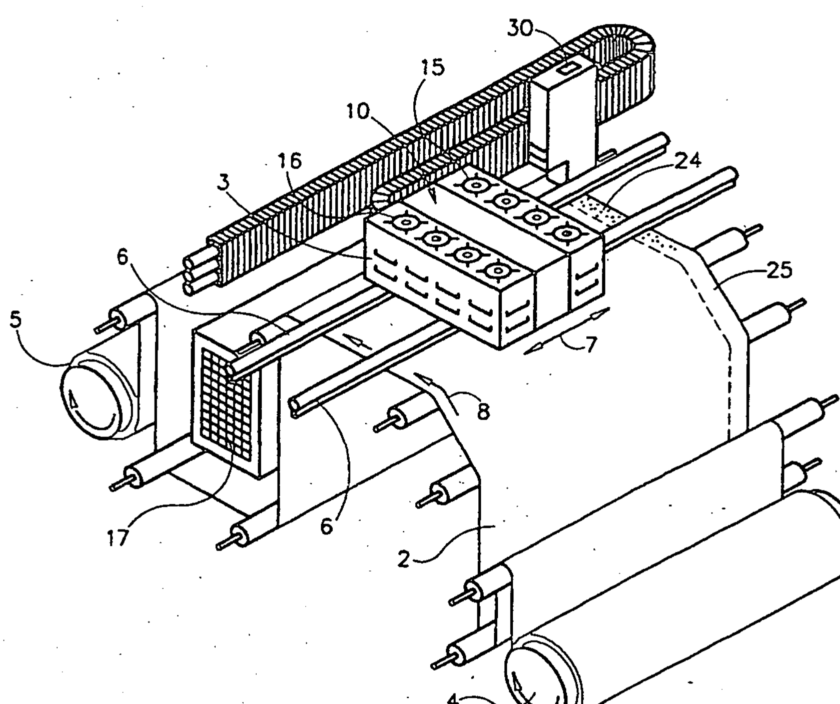
(54) Title: INK-JET PRINTING APPARATUS AND METHOD

(57) Abstract

A method and apparatus are described for operating an ink-jet printer (10) by: controlling the printer's nozzles (20) to print a pattern of test marks (24) on a test strip (25) while relative movement is effected between the printhead (11) and the test strip (25); sensing and analyzing the pattern of test marks (24) with respect to a number of printing parameters to detect errors and to determine whether such errors are within predetermined tolerance limits; automatically controlling the plurality of nozzles (20) to compensate for those errors within the predetermined tolerance limits; and automatically terminating the operation of the printer (10) upon detection of an error exceeding a predetermined tolerance limit.



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INK-JET PRINTING APPARATUS AND METHOD

FIELD AND BACKGROUND OF THE INVENTION

The present relates to ink jet printing and particularly to a method and apparatus for sensing and for correcting certain types of errors in the operation of an ink jet printer.

Continuous ink jet printers are based on stimulated formation of the ink drops from a continuos ink jet filament at a rate determined by an external perturbation source. The ink drops are selectively charged and deflected according to an external data source such that ink drops emitted from the nozzle of the printing head selectively impinge on a substrate and generate a printing or marking pattern on it.

The charges carried by the drops are defined by the field to which the filament is subject at the instant of drop break-off from the jet filament. Typically, the ink is conductive, and the jet filament functions as an electrode which provides the charges necessary to charge the drops. The external charging filed is typically provided by close-by electrodes in a capacitive arrangement relative to the jet filament.

Continuous ink jet printers are divided into two types of systems: binary, and multi-level. In binary systems, the drops are either charged or uncharged and accordingly either reach or do not reach the substrate at a single predetermined position. In multi-level systems, the drops can receive a large number of charge levels and accordingly can generate a large number of print positions.

The process of drop formation depends on many factors associated with the ink rheology (viscosity, surface tension), the ink flow conditions (jet diameter, jet velocity), and the characteristics of the perturbation (frequency and amplitude of the excitation). Typically, drop formation is a fast process, occurring in the time frame of a few microseconds. However, because of possible variations in one or more of the several factors determining the drop formation, there are possible variations in the exact timing of the drop break-off. These timing variations, which can be described by phase shifts in the period of drop break-offs, can cause

incorrect charging of drops if the electrical field responsible for drop charging is turned-on or turned-off (or changed to a new level) during the drop break-off itself. Therefore it is necessary to keep the data pulse in-phase relative to the drop break-off timing, in order to obtain accurate drop charging and printing.

Previous continuous ink jet systems which contain a typical nozzle diameter of 35-70 μ operate at relatively high drop generation frequencies, typically higher than 60 kilohertz. Therefore, the drop cycle period is small, in the order of 15 microseconds, and the drop formation time corresponds to about 20% or more of the drop cycle period. This indicates that phase control in continuous ink jet systems has to be very tight in order to guarantee correct operation continuously.

Many techniques for phase control have been devised. Some drops are cyclically or constantly monitored for the value of charge they carry by using sensitive electrometers. These electrometers are prone to EMI and RFT interference; also because of the need to place them very close to the stream of drops, serious maintenance problems might develop.

In multi-jet systems, the use of electrometer based phase sensing for each jet in the head becomes extremely difficult and costly. Therefore, techniques were devised to overcome phasing problems which are based not on direct sensing of drop charges, but rather on the design and/or direct sensing of the excitation signal itself. However, these techniques were also found to be extremely complicated and also only partially accurate, particularly with ink printers having a large number of nozzles. Examples of known systems are described in US Patents 4,590,483, 5,408,255 and 5,502,474.

OBJECTS AND BRIEF SUMMARY OF THE PRESENT INVENTION

An object of the present invention is to provide a method of operating an ink-jet printer in a test mode in order to detect and to compensate for certain types of printing errors generated by the printer. Another object of the invention is to provide ink-jet printing apparatus permitting certain types of printing errors to be detected and compensated for in a convenient manner.

According to one aspect of the present invention, there is provided a method of operating an ink-jet printer having a print head including a plurality of nozzles each emitting, towards a substrate, a series of ink drops broken-off from a continuous ink jet filament while effecting relative movement between the print head and the substrate, and while selectively charging and deflecting the drops according to a pattern of marks to be printed by the respective nozzle on the substrate, comprising: controlling the plurality of nozzles to print a pattern of test marks for each nozzle on a test strip while relative movement is effected between the print head and the test strip; sensing the patterns of test marks; analyzing the patterns of test marks with respect to a number of printing parameters to detect printing errors and to determine whether such errors are within predetermined tolerance limits; automatically controlling the plurality of nozzles to compensate for those errors within the predetermined tolerance limits; and automatically terminating the operation of the printer upon detection of an error exceeding a pretermined tolerance limit.

According to further features in the described preferred embodiments, the printing parameter errors to be detected include phase errors caused by incorrect timing of the charging of the drops with the formation of the drops from a nozzle, which phase errors are automatically compensated for by controlling the timing of the charging pulses applied to the drops in the respective nozzle; and velocity errors caused by incorrect velocity of the drops emitted by a nozzle, which velocity errors are automatically compensated from the respective nozzle.

In one preferred described embodiment, the printing parameter errors to be detected also include: X-axis offset errors and Y-axis offset errors caused by

incorrect alignment of a nozzle with respect to the X-axis and Y-axis respectively, and angular offset errors caused by assymetry of the electrical field between the deflection plates associated with a nozzle. The X-axis offset errors are automatically compensated for by controlling the magnitude of the charging pulses applied to the drops in the respective nozzle; whereas the Y-axis and angular offset errors are automatically compensated for by restructuring the printing data.

In one described embodiment, the test strip is part of the substrate and is located laterally of the portion of the substrate to receive the printed marks during a normal operation of the printer; and in another described embodiment, the test strip is a separate strip from the substrate. In the latter described embodiment, the test strip may be inserted into the printer in place of the substrate (intended to receive the normal printing) whenever a pattern of test marks is to be printed and while the print head is in its normal printing position to print on the substrate.

According to another aspect of the present invention, there is provided an ink-jet printing apparatus, comprising; a print head having a plurality of nozzles each for emitting a series of ink drops towards a substrate while relative movement is effected between the print head and the substrate; an electrical charger and an electrical deflector for selectively charging and deflecting the drops according to a pattern of marks to be printed on the substrate; a processor programmed to control the print head and the electrical charger to cause the nozzles to emit ink drops, and the charger to charge the ink drops, according to the pattern to be printed on the substrate; the processor also being programmed to control the plurality of nozzles to print a pattern of test marks for each nozzle on a test strip; and a sensor for sensing the pattern of test marks for each nozzle and for producing output signals to the processor corresponding to the patterns of test marks.

As will be described more particularly below, the foregoing features of the method and apparatus of the present invention enable ink jet printers to be

constructed and operated in a manner which permits errors in the operation of the printer to be easily detected and conveniently compensated for.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 schematically illustrates one form of ink jet printing apparatus constructed in accordance with the present invention;

Fig. 2 more particularly illustrates the print head assembly in the apparatus in of Fig. 1;

Fig. 3 schematically illustrates the multi-level printing system in the apparatus of Figs. 1 and 2;

Fig. 4 is a three-dimensional view more particularly illustrating the optical sensor device in the apparatus of Fig. 1;

Figs. 5 and 6 are diagrams helpful in explaining the manner of detecting phase and velocity errors, respectively, in accordance with one aspect of the invention;

Fig. 7 is a block diagram schematically illustrating one form of control system for controlling the printing apparatus of Fig. 1;

Figs. 8a and 8b, taken together, represent a flow chart describing one manner of operating the system of Fig. 5;

Fig. 9 illustrates an optical sensor (a CCD camera) mechanically coupled to the printing head of the apparatus so as to be moved therewith during the scanning of the test strip;

Fig. 10 illustrates an optical sensor (CCD camera) for sensing the test marks being applied to a test strip which is automatically placed in front of the print head during test printing;

Fig. 11 illustrates one form of test pattern that may be printed on the test strip;

Fig. 12 is an enlarged view of a portion of the test pattern of Fig. 11; and

Fig. 13 is a flow chart illustrating the manner of operating the printer when using the test pattern of Fig. 11.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The apparatus illustrated in Fig. 1 is an ink jet printer printing multi-color ink patterns on a substrate 2 (e.g., a paper, plastic or fabric web) fed past a print head assembly 3 from a supply roll 4 to a take-up roll 5. The print head assembly 3 is continuously driven back and forth on a pair of tracks 6 extending transvesely across the substrate 2, as shown by arrow 7; whereas the substrate 2 is driven in steps in the longitudinal direction, as shown by arrows 8, between the supply roll 4 and the take-up roll 5.

As shown particularly in Fig. 2, print assembly 3 includes a multiple-color print unit 10, constituted of four monochrome print heads, namely a black print head 11, a magenta print head 12, a yellow print head 13, and a cyan print head 14, for printing the four process colors (K M Y C). The print heads are arranged in a line extending perpendicularly to the path of movement of the print assembly 3 on tracks 6. Each print head 11-14 includes a plurality of nozzles emitting a series of ink drops towards the substrate 2.

Print head assembly 3 further includes a pair of curing units 15, 16 straddling the opposite sides of print unit 10 and effective to dry the ink applied to the substrate during both directions of movement of the print assembly 3 transversely across the substrate. Each curing unit 15, 16 may be of the ultraviolet or infrared type, according to the printing ink used. The apparatus may further include a fixed dryer unit 17 (Fig. 1) extending transversely across the substrate path of movement.

Each of the print heads 11-14 includes an array of nozzles 20 extending transversely across the path of movement of the print assembly 3, i.e., parallel to the path of movement of the substrate 2. The nozzles may be arrayed in a single column, but preferably are arrayed in a plurality of columns in non-overlapping staggered relationship to each other to provide a high density nozzle array for purposes of example, Fig 2 and 3 illustrate four columns with each column including eight nozzles. As known in ink jet printers of this type, each nozzle emits a series of ink drops towards the substrate 2 and selectively charges the

drops according to the marks to be printed by the respective nozzle on the substrate.

During the actual printing, the motion of the print assembly 3 is continuous and uniform, while the substrate is kept static. When the print assembly 3 reaches its limit of travel in the transverse direction, it reverses and travels transversely across the substrate in the reverse direction. During the movement reversal time, the substrate is advanced one step to align a new transverse sector of the substrate with the print assembly.

All four monochrome heads 11-14 are operated to print all the process colors K M Y C during each transverse movement of the print assembly 3, but the substrate 2 is stepped only the length (in the arrow 8 direction, Fig. 1) of one of the print heads, i.e., one-fourth the length of all four monochrome heads. Thus, only one head (e.g., the C-head 14 in Fig. 2) overlies a new sector of the substrate during each transverse movement of the print assembly.

Fig. 3 schematically illustrates how each nozzle 20 of each of the four monochrome heads 11-14 emits a series of ink drops towards the substrate 2 and selectively charges the drops according to the marks to be printed by the respective nozzle on the substrate. Thus, as shown in Fig. 3, the ink drops 21 emitted by the respective nozzle 20 first pass between a pair of charging electrodes 22 which charge each ink drop. Each drop then passes between a pair of deflecting electrodes 23 which deflect the ink drop according to the applied charge before the ink drop impinges the substrate 2.

If the printer is of the binary-charge type, the drops are either charged or uncharged, and accordingly either reach or do not reach the substrate at a single predetermined position. For example, if the drop is to be printed, it would be charged; and if not to be printed, it would be uncharged and would be received by a gutter, shown at 26 in Fig. 3, and not on the substrate. The binary-charge system may also be of the inverse type, wherein an uncharged drop is printed and a charged drop is not printed.

The preferred embodiment of the invention described herein is based on a multi-level charge system, wherein the drops can receive a large number of

charge levels, and accordingly can generate a large number of print positions. Typical multi-level systems operate according to 8, 10, 12 or a higher number, of charge levels. For example, a print head including 120 nozzles operating according to 8 levels provides approximately 100 DPIs (dots per inch), whereas one operating at 10 levels provides approximately 120 DPIs, and one operating at 12 levels provides approximately 140 DPIs.

In the preferred embodiments of the invention described herein, the multi-level charges include: (a) a "0" charge when the ink drop is to be received undeflected on a substrate; (b) a plurality of different-level charges of one sign according to the amplitude of deflection to be applied to the ink drop before received on the substrate; and (c) a charge of the opposite sign when the ink drop is to be received not on the substrate but rather on the gutter.

According to the present invention, the nozzles 20 of each of the print heads 11-14 are controlled to print a pattern of test marks 24 on a test strip 25 e.g., one side of the substrate 2 or a separate strip. These test marks are printed at the end of the respective transverse path of the print head, either immediately before the deceleration starts for the reverse path, or after the acceleration in the reverse path has been completed, so that the print head motion is uniform during the printing of the test pattern 24.

As shown in Fig. 4, the apparatus further includes a sensor 30 for sensing the pattern of test marks 24 on the test strip 25 Preferably, sensor 30 is an optical sensor, namely a CCD camera aligned with test strip 25. Optical sensor 30 includes a light source 31 for illuminating test strip 25, and a lens system 32 for focussing the light reflected from the test strip 25 onto the CCD cells 34 of the camera. Preferably the sensor is fixed with respect to the printer, but would be adjustable both horizontally and vertically to allow optimum alignment of the CCD cells with the test strip 25.

The pattern of test marks 24 on the test strip 25, as sensed by the CCD cells 34, is analyzed, e.g., with respect to a stored reference pattern representing proper operation of each of the print heads 11-14 of the apparatus, such that any discrepancies between the sensed test pattern and the reference pattern indicate

improper operation of the printer. As will be described below, these discrepancies between the two patterns can be used for identifying the printing error, and for providing appropriate feedback control signals to the system controller 43 (Fig. 7) for compensating for these errors.

More than one sensor can be mounted side-by-side in order to obtain a larger field of view without increasing the sensor height, or in order to obtain higher exposure resolution, i.e., more CCD cells per specific feature. The sensor is able to detect all colors, as a dynamic threshold tuning can be used. The gathered information is mainly the edges of the dots, and therefore it is easy to obtain good signals from the CCD sensor even with the limited dynamic range of such sensors since a dot can be defined by a minimal number (e.g., 5) of CCD cells.

Preferably, each dot on the test strip 25 is sensed by several CCD cells in the camera 30. Calculation of the location of the dot centers provides useful information indicating the presence, type and location of printing errors.

One type of commonly-occurring printing error is incorrect phasing of the charging pulse with the break-off time of the ink drop as it passes between the charging electrodes 22 so that the ink drop is not properly deflected onto the substrate. Another type of error is an incorrect velocity of the ink drops 21, so that the ink drop is not deflected to its proper position of impingement on the substrate 2. The above-described multi-level charges applied to the ink drops for printing purposes may also be used for sensing both types of errors. One method that may be used is as follows.

The "0" charge, which is applied during the printing phase to the ink drops to be received undeflected onto the substrate, will also indicate, during the test cycle, whether the charging pulses are correctly phased with the break-off times of the drop emitted from the respective nozzle. Thus, the absence of a test mark produced by a nozzle when a "0" charge is applied indicates that the charging pulses for the nozzles are incorrectly phased with respect to ink drop break-off times in the respective nozzle. This is shown particularly in Fig. 5, wherein it will be seen that when the charging pulses for the nozzles are correctly

phases with respect to ink drop break-off times, a mark 24 will be printed in its proper place on the test strip 25 for each "0" charge pulse of each nozzle, and will be sensed by the CCD camera; whereas if there is an incorrect phasing between the charging pulses and the ink break-off times for the respective nozzle, the mark for the "0" charge will be misplaced, and therefore the output of the CCD camera will indicate this incorrect phasing. Such an incorrect phasing may be compensated for by adjusting the phase of the charging pulse applied to the electrodes 22 in the respective nozzle 20. A missing mark for a nozzle indicates the nozzle is clogged or grossly misdirected.

Although it would be theoretically sufficient for each nozzle to print (or not print) a single dot in the test strip 25, preferably the nozzles are controlled to print marks constituted of a series of dots. The result is a bar code, rather than dot code, which decreases the alignment problems between the camera 30 and the marks 24 on the test strip 25 of the substrate. However, since the CCD cells 34 are of smaller size than the dots, a dot will also appear as a "bar" to the CCD cells.

The errors caused by the incorrect velocity of the ink drops, as they pass between the deflecting electrodes 23, are indicated in Fig. 6. They are detected by the plurality of different-level charges of one sign applied to the deflecting electrodes according to the amplitude of deflection to be applied to the ink drops during the printing cycles. Thus, by measuring the spacing between the bars in the bar pattern produced on the test strip 25, and comparing that spacing with a reference pattern, or reference information, representing proper operation of the printer, any discrepancies between the spacings in the two patterns will indicate improper deflection of the ink drops, and thereby incorrect velocity of the drops passing between the deflector plates 23.

Jet speed errors may be produced by many different factors as indicated earlier. In the preferred embodiment of the invention described below, such errors are compensated for by changing the charging voltage applied to the ink drops, since the amount of deflection to be experienced by the ink drops before

impinging the substrate depends on the ink jet speed (second power), and the voltage applied by the deflector plates.

Fig. 7 schematically illustrates the overall control system of the apparatus. It includes a processor 40 which receives the pattern of test marks on the test strip 25 as sensed by the CCD camera 30, and compares it with the reference pattern as inputted by an input device 41 and as stored in its memory 42. The detected deviations between the two patterns are outputted to the system controller 43 having an input device 44.

Thus, printing errors resulting from incorrect phasing between the charging pulses applied to the ink drops from a nozzle and the ink drop break-off times, as determined in processor 40, are compensated for by the system controller 43 by controlling a phase-shifter circuit 45 for the respective nozzle. Printing errors resulting from an incorrect speed in the ink drops emitted by the nozzles are compensated for by the system controller 43 by adjusting the voltage applied to the drops by the charging circuit 46 for the respective nozzle.

System controller 43 further controls the printer mechanical drive 48, the printer electrical drive 49, the substrate mechanical drive 50, and a display 51 to enable monitoring the overall operation of the apparatus.

OPERATION

A preferred manner of operating the described apparatus is shown in the flow chart of Figs. 8A and 8B.

With the print head assembly 3 in test position, i.e., with its nozzles aligned with test strip 25 of the substrate 2 (block 60), the nozzles are simultaneously energized to produce the same print phase pattern from each nozzle, (block 61), namely a drop of ink emitted from each of the nozzles and receiving a "0" charge. The test marks so produced on test strip 25 are sensed by CCD camera 30 (block 62), and the information is fed to processor 40. The processor analyzes this information, e.g., from a look-up table (LUT) corresponding to a reference pattern and stored in processor 40, for the following deviations from the reference pattern:

(a) a missing dot (block 63) which indicates a serious malfunction, such as a clogged nozzle or a non-aligned nozzle, and therefore serves to terminate the operation of the printer (64);

(b) an excessively-large deviation of spacing between the drops, i.e., one considerably above a predetermined tolerance limit (block 65); this is also considered to be a major malfunction and serves to terminate the operation of the printer (block 64);

(c) a minor deviation (i.e., within a predetermined tolerance limit) in the spacing between drops, which indicates an error in the charging phase of the respective nozzle (block 66). This is compensated for by controlling phase shifter 45 (Fig. 7) for the respective nozzle to shift the phase (timing) of the charging pulse in an arbitrary direction by a time (Tc) which is equal to or greater than the charging time (block 67). The pattern is again printed, and if the result is still not correct, the phase is shifted by 2Tc in the other direction, etc., until the pattern is correct.

The foregoing phase test procedure is repeated for all four monochrome heads (block 68).

A print cycle is then initiated (block 69), during which the print head assembly 3 is moved transversely of the substrate 2 along track 6 in one direction (block 70), and then in the opposite direction (block 71).

With the print head assembly 3 back in the test position, aligned with the test strip 25 (block 72), a multi-level test pattern is simultaneously printed from all the nozzles of one monochrome head 11-14 on the test strip 25. That is, each nozzle is sequentially controlled to print a raster of at least two (e.g., six) drops, one of which is a "0" charge drop, and the other drops charged with different voltages according to the multi-level system used. For example, Fig. 6 illustrates an eight-level system, in which the velocity pattern applied to each nozzle includes a "0" charge, a second-level charge, a fourth-level charge, a sixth-level charge, and an eighth-level charge.

After this velocity test pattern has been printed from one monochrome head (block 74), the test marks are analyzed for ink velocity errors.

In a multiple-nozzle system, one way to control the ink jet velocity is via the inlet pressure and viscosity, in which case the inlet pressure and ink viscosity are sensed, compared to pre-prepared data, such as data stored in a look-up table relating to pressure, speed, viscosity, pump speed, etc., and controlled according to the data in the look-up table. Although this is a common correction of the entire number of jets, the specific jet velocity will always have some uncertainty factors which will not be able to be corrected through this type of control, because of the tolerances in the nozzle manufacturing, etc.

On the other hand, detecting and correcting, or compensating for, ink velocity errors is quite important as the deflection of ink drops is related to the square of the speed. In the apparatus of the present invention, such velocity errors within a permissible correction range are compensated for by changing the charging voltage applied to the ink drops for the entire raster.

Speed errors (SE) are defined as:

SE= (Pi, real, Po, real)-(Pi, data-Po, data)

where:

Pi, data: the desired location of the "i" drop in the raster

Pi, real: the real location of the "0" charged drop in the raster

Po, data: the desired location of he "0" charged drop in the raster

Po, real: the real location of the "0" charged drop in the raster

The speed errors are compensated for by controlling the charging circuit (46, Fig. 7) for the respective nozzle according to a voltage adjustment determined, e.g., through a look-up table stored in processor 40.

Before such speed errors are compensated for, however, the processor checks to see whether the error is within a predetermined tolerance or correction range (block 76). If so, it adjusts the charging voltages (block 77) and continues the print cycle (block 78); but if not, it terminates printing (block 79).

The foregoing procedure for testing one monochrome head is repeated for the other three monochrome heads (blocks 80, 81, 82).

At periodic intervals, the above-described phase and velocity checks may be repeated and compensated for, and the printing continued (blocks 83-86).

For small length test strips, a single CCD camera 30 could be used to sense the whole strip length of four colors. For longer test strips, four CCD cameras could be used, one for each color, to simultaneously control the performance of each color head. In this described embodiment, the colors are sequentially printed and sensed. The cycle time between a first color sensing and a second color sensing corresponds to a full back-and-forth print cycle. Thus, the time between successive sensing of a same color is four back-and-forth print cycles.

For example, the print head assembly may move at uniform speed of 0.8 m/s during printing, and may spend one second during each direction reversal. For a typical print width of 1.6 m, the color-to-color cycle time would be four seconds, and the sensing period for a single color would be 16 seconds. In systems where the combination of system and ink characteristics requires phase correction more frequently than in this example, more than one camera can be used to reduce the sensing period.

The above-described technique is especially suitable for a multi-jet system including a high-viscosity low-speed jet, and a relatively low frequency of drop generation, as described for example in Patent Application Serial No. 08/734,299, filed October 21, 1996, assigned to the same assignee as te present application, the entire content of which is incorporated herein by reference. In such a system, the drop cycles are considerably longer (typically above 35 microseconds), and the drop formation time corresponds to less than 10% of the cycle. Therefore, it takes longer for the system to drift or swing out of phase, and it is possible to monitor the actual printed pattern at longer periods ranging from a few seconds to a few tens of seconds.

Non-colored inks (e.g., varnish) can be easily sensed using the near IR range (around 800 nm). Contrast problems may occur on bright white media, in which case a pre-print line could be printed before the varnish line is applied. This should not be a problem as the varnish is always applied after the primary printing. If color toning is to be used in the printing process, e.g., by diluting the ink, etc., the same sensor can also be used for quantify color coordinates of the

basic colors and to send the information to the main control. Thus, inline correction can be made to assure color repeatability and quality. In this case, the line CCD sensor and the illumination must be carefully selected, or four different sensors can be mounted, one for each color range.

FURTHER VARIATIONS

Fig. 9 illustrates a variation wherein the print head 100, movable transversely across the substrate 102 as shown by arrow 103, is mechanically coupled to the optical sensor 104 via a coupling member 105 so that the optical sensor moves with the print head not only when the print head prints the substrate 102, but also when it prints the test marks on the test strip 106.

Fig. 10 illustrates a variation wherein the print head 100 is used for printing on a substrate in the form of a packaged article 107. In this case, the test strip is not a part of the substrate 107, but rather is a separate strip, as shown at 108, which may be automatically inserted in place of the substrate whenever a pattern of test marks is to be printed, and while the print head is in its normal printing position to print on the packaged article 107. In the variation illustrated in Fig. 10, the optical sensor 104 is also coupled, e.g. by coupling members schematically indicated at 109, to the print head 100.

Fig. 11 illustrates a test pattern that may be printed on the test strip in order to detect and compensate for a wider variety of printing errors than those described earlier, and Fig. 12 enlarges a portion of the test pattern of Fig. 11. Using this test pattern enables the detection of not only phase and velocity errors, but also spatial offset errors, namely X-offset, Y-offset and angular-offset errors. A further advantage is that only a single test pattern needs to be printed (rather than the separate "phase" and "velocity" patterns described earlier); and a still further advantage is that it enables the better detection of a phase error and also the phase location for such an error.

The spatial offsets are more particularly shown in Fig. 12, which illustrates one line of nozzles N_1—N_n, corresponding to the line of nozzles 20

illustrated in Fig. 3. This line of nozzles defines the X-axis. As shown in Fig. 3, the ink drops emitted by each nozzle are deflected by the deflection plates 23 according to the charge level applied by the charging plates 22, such that the X-axis also constitutes the deflection or raster axis of the ink drops emitted by each nozzle when the multi-level charges are applied. The Y-axis in Fig. 11 is the scanning axis, i.e. the direction of relative movement between the substrate (or test strip) with respect to the line of nozzles N_1-N_n during the operation of the printer.

Fig. 12 more particularly illustrates the spatial offset errors as follows:

(a) the X-offset error (shown as Δx in Fig. 12) is the lateral amount (in the deflection or raster direction, i.e. the X-axis) by which the line of the pixel positions (produced by the ink drops) corresponding to the "0" charge level (undeflected by the deflecting plates 23, Fig. 3) deviates from the nominal nozzle position (indicated at N_1—N_n, respectively);

(b) the Y-offset error (shown as ΔY in Fig. 12) is the spatial amount in the scanning direction (Y-axis) by which the raster line generated by each nozzle deviates from the "mean" raster line position (Y-axis) for all nozzles.

(c) the angular offset error (shown as θ in Fig. 12) is the angular amount by which the line raster segment produced by the multi-level deflections of the respective nozzle deviates from the X-axis.

X-offset (Δx) errors and Y-offset (Δy) errors can be caused by several factors, including: misalignment of the nozzle axis; residual drop charging due to the field of the deflection plates; and partial clogging of the nozzle. Angular offset (θ) errors are predominately caused by asymmetry of the electrical field between the deflection (plates 23, Fig. 3) associated with a nozzle.

The single test pattern illustrated in Fig. 11 includes three regions, identified as R_A,R_B and R_C, respectively.

In region R_A, only one single drop, corresponding to the "0" charge drop, is printed from each of the nozzles N_1—N_n. The result is a line along the Y-axis

for each nozzle. Thus, the test pattern in region R_A is similar to that described above with respect to Fig. 5, and can be used in the same manner as described above for detecting phase errors, clogged nozzles, or grossly misdirected nozzles. However, as will be described more particularly below, the information obtainable from region R_C of the test pattern illustrated in Fig. 11 can be used for detecting the same errors, and therefore the test pattern need not include region R_A, but could include only regions R_B and R_C, these being the regions illustrated in Fig. 11.

Test pattern region R_B of Fig. 11 is generated simultaneously for all the nozzles N1-Nn by applying the sequence of the multi-level voltages to each nozzle. The result is a printed line segment along the X-axis for each of the nozzles N_1—N_n. These line segments are shown as XS_1—XS_n in Figs. 11 and 12. As shown particularly in Fig. 12, this test pattern region R_B is used for determining the X-offsets (Δx), the Y-offsets (Δy), and the angular offsets (θ).

To produce test pattern region R_C of Fig. 11, each nozzle is caused to emit a series of ink drops while the charging plates (22, Fig. 3) are scanned from 0-360°, and while the test strip is moved along the Y-axis. Each nozzle is thus phase-swept 0°-360° for at least two charge levels, preferably the "0" charge level and the highest charge level. As a result, two Y-axis (i.e., scanning direction) lines, one for each charge level, is produced from each nozzle (shown as "YL_{1a}, YL_{1b} for nozzle N_1, etc). The so-produced region R_c of the test pattern illustrated in Fig. 11 can be used for detecting both phase errors and velocity errors in the following manner:

Where no phase errors occur, the Y-axis line (YL_{1a}, YL_{1b} for nozzle N_1) will be straight and unbroken. However, where an out-of-phase condition is present in a nozzle, the respective line will be broken, fuzzy, or non-linear, at the location where the out-of-phase condition occurs. Therefore, region R_c of the test pattern illustrated in Fig. 11 may be used for detecting both the occurrence and the location of phase errors.

The spacing along the X-axis between the two Y-axis lines produced in regions R_c of Fig. 11 (e.g. between lines YL_{1a} and YL_{1b} for nozzle N_1), called the "pair width", is a function of the ink drop velocity in the respective nozzle. It also incorporates possible deviations in the separation between the substrate and the end edge of the deflection plates (print distance). Thus, where the pair width of two lines is narrower than the mean pair width for all the nozzles, this indicates an ink drop velocity at that nozzle above the mean velocity for all the nozzles; and conversely, where the pair width is larger than the mean pair width, this indicates an ink drop velocity for the respective nozzle below the mean velocity for all the nozzles.

An important feature of the apparatus of the present invention is that the detection of a printing error does not require the immediate correction of the condition causing the error; for if it did, operation of the apparatus would involve substantial non-productive periods for maintenance purposes. Rather, the illustrated apparatus, upon detection of an error, automatically provides compensation to eliminate or minimize the effects of the condition causing the error and thereby to prevent a malfunction condition which requires correcting of the apparatus. If, however, a detected error exceeds a pretermined tolerance limit, the condition is then treated as a malfunction or failure, and automatically terminates the operation of the apparatus to enable the condition causing the malfunction to be corrected.

Fig. 13 is a flow chart illustrating the operation of the printing apparatus shown in Fig. 7 but using the single test pattern illustrated in Fig. 11 for detecting the various types of printing errors as described earlier.

Thus, as shown in Fig. 13, with the print head (10, Fig. 7) in test position (block 110), the test pattern is printed on the test strip (block 111) which, as described earlier, may be part of the substrate and located laterally of the portion thereof to receive printed marks during a normal printing operation as described above with respect to Fig. 1, or a separate test strip as described above with respect to Fig. 10.

The test pattern is first checked for serious malfunctions, such as missing dots (block 113) excessive misalignment of a nozzle (block 114), etc.; and if such a serious malfunction is detected, the operation of the apparatus is automatically terminated (block 115) to permit the condition causing the malfunction to be corrected.

If such a malfunction is not detected, the processor 40 processes the image test pattern sensed by the CCD camera 34 and determines the presence and parameters of X-offset, Y-offset, angular-offset, velocity and phase errors (block 116) as described above with reference to Figs. 11 and 12.

An automatic check is made to determine that all the detected errors are within pretermined limits (block 117), and if a limit is exceeded, this is again considered to be a serious malfunction which causes the processor 40 to automatically terminate the operation of the apparatus (block 118) via controller 43.

In the absence of such a malfunction, the processor automatically compensates for any detected errors, by sending correction signals to the controller 43 (Fig. 7), as follows:

(a) phase errors, caused primarily by incorrect timing of the charging of the drops with the formation of the drops in a nozzle, are automatically compensated for by control signals from controller 43 to the phase shifter circuit 45 to control the timing of the charging pulses applied to the drops from the respective nozzle;

(b) velocity errors, caused primarily by incorrect velocity of the drops emitted by a nozzle, are automatically compensated for by control signals from controller 43 to the charger circuit 46 to control the magnitude of the charging pulses applied to the drops in the respective nozzle;

(c) X-offset errors, caused primarily by incorrect alignment of a nozzle with respect to the X-axis, are automatically compensated for by control signals

from controller 43 to the charger circuit 46 to control the magnitude of the charging pulses applied to the drops in the respective nozzle;

(d) Y-axis offset errors, caused primarily by incorrect alignment of a nozzle with respect to the Y-axis, are automatically compensated for by processor 40 to restructure the timing of the printing data;

and (c) angular offset errors, caused primarily by asymmetry of the electrical field the deflection plates associate with a nozzle, are automatically compensated for also by processor 40 to restructure the timing of the printing data.

When restructuring the timing of the printing data in to compensate for Y-offset errors, the preceding rasters (positive offset) are delayed, and the lagging rasters (negative offset) are anticipated; the data in the raster itself remains unchanged. When restructuring the timing of the printing data for compensating for angular-offset errors, complimentary corrections are made as when compensating for Y-offset errors. The compensations for the other errors may be according to lookup tables maintained in the processor 40, or according to appropriate correction algorithms preprogrammed in the processor.

After the detected errors have been compensated for in the manner described above, the calibration file maintained by the processor 40 is updated (block 120). If the printer is monochrome, a print cycle is initiated (block 121), and a pretermined number of print data sweeps are performed (block 122), before the print head is returned back to its normal test position (block 123). If the printer is a color printer (block 124), the foregoing steps are repeated for all the colors (block 125).

While the invention has been described with respect to several preferred embodiments, it will be appreciated that these are set forth merely for purposes of example, and that many other variations, modifications and applications of the invention may be made.

CLAIMS

1. A method of operating an ink jet printer having a print head including a plurality of nozzles each emitting, towards a substrate, a series of ink drops broken-off from a continuous ink jet filament while effecting relative movement between the print head and the substrate, and while selectively charging and deflecting said drops according to a pattern of marks to be printed by the respective nozzle on the substrate, comprising:

   controlling said plurality of nozzles to print a pattern of test marks for each nozzle on a test strip while relative movement is effected between the print head and the test strip;

   sensing said patterns of test marks;

   analyzing said patterns of test marks with respect to a number of printing parameters to detect printing errors and to determine whether such errors are within predetermined tolerance limits;

   automatically controlling said plurality of nozzles to compensate for those errors within said predetermined tolerance limits;

   and automatically terminating the operation of said printer upon detection of an error exceeding a pretermined tolerance limit.

2. The method according to claim 1, wherein said pattern of test marks is the same for all the nozzles and is printed simultaneously by all the nozzles.

3. The method according to claim 1, wherein said printing parameter errors to be detected include phase errors caused by incorrect timing of the charging of said drops with the formation of said drops in a nozzle; said phase errors being automatically compensated for by controlling the

timing of the charging pulses applied to said drops in the respective nozzle.

4. The method according to claim 1, wherein said printing parameter errors to be detected include velocity errors caused by incorrect velocity of the drops emitted by a nozzle; said velocity errors being automatically compensated for by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

5. The method according to claim 1, wherein said test strip is part of said substrate and is located laterally of the portion of the substrate to receive the printed marks during a normal operation of the printer.

6. The method according to claim 1, wherein said test strip is a separate strip from said substrate to receive the printed marks during a normal operation of the printer.

7. The method according to claim 6, wherein said test strip is inserted in place of the substrate whenever a pattern of test marks is to be printed and while the print head is in its normal printing position to print on the substrate.

8. The method according to claim 1, wherein said pattern of test marks is sensed by an optical sensor.

9. The method according to claim 8, wherein said optical sensor is coupled to said print head so as to move therewith.

10. The method according to claim 1, wherein said printing parameter errors to be detected include:

phase errors caused by incorrect timing of the charging of said drops with the formation of said drops in a nozzle, which phase errors are automatically compensated for by controlling the timing of the charging pulses applied to said drops in the respective nozzle; and

velocity errors caused by incorrect velocity of the drops emitted by a nozzle, which velocity errors are automatically compensated for by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

11. The method according to claim 10, wherein said printing parameter errors to be detected also include X-axis offset errors caused by incorrect alignment of a nozzle with respect to the X-axis, which X-axis offset errors are automatically compensated for by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

12. The method according to claim 11, wherein said printing parameter errors to be detected further include Y-axis offset errors caused by incorrect alignment of a nozzle with respect to the Y-axis, which Y-axis offset errors are automatically compensated for by restructuring the timing of the printing data.

13. The method according to claim 12, wherein said printing parameter errors to be detected further include:

angular offset errors caused by asymmetry of the electrical field between the deflection plates associated with a nozzle which angular-offset errors are automatically compensated for by restructuring the printing data.

14. The method according to claim 13, wherein said printing parameter errors are detected by performing a series of test operations, including:

(a) effecting relative movement between the print head and the test strip along the Y-axis;

(b) sequentially applying multi-level charging pulses to each nozzle to produce printed marks defining an X-line segment for each nozzle along the deflection direction (X-axis), and

(c) sequentially scanning from 0° through 360° the phase of the charging pulses applied to each nozzle at each of a first and a second charge level to produce two printed parallel lines of marks for each nozzle along the scanning direction (Y-axis);

said two printed parallel lines along the scanning direction (Y-axis) produced during operation (c) being straight and unbroken in the absence of a phase error, and being broken, fuzzy or non-linear at the phase where a phase error occurs, thereby indicating the presence of a phase error and the phase at which such error occurs;

the spacing in the deflection direction between said two printed parallel lines produced during operation (c) indicating the presence and magnitude of a velocity error;

the lateral amount in the deflection direction by which the line of marks printed at said first charge level of each nozzle during operation (c) deviates from the nominal position of the nozzle, indicating the presence and magnitude of an X-axis offset error;

the spatial amount in the scanning direction by which the raster line generated by each nozzle during operation (c) deviates from the "mean" raster line for all nozzles, indicating the presence and magnitude of a Y-axis offset error; and

the angular amount by which said X-line segments printed during operation (b) deviates with respect to the deflection direction, indicating the presence and magnitude of an angular offset error.

15. A method of operating an ink jet printer having a print head including a plurality of nozzles each emitting, towards a substrate, a series of ink drops broken-off from a continuous ink jet filament while effecting relative movement between the print head and the substrate, and while selectively charging and deflecting said drops according to a pattern of

marks to be printed by the respective nozzle on the substrate, comprising:

controlling said plurality of nozzles to print a pattern of test marks for each nozzle on a test strip while relative movement is effected between the print head and the test strip;

sensing said patterns of test marks by a sensor coupled to said print head to move therewith;

analyzing said patterns of test marks for proper operation of the printer;

and producing an output signal indicating errors in the operation of the printer.

16. The method according to claim 15, wherein said patterns of test marks are analyzed with respect to a number of printing parameters to detect errors therein and to determine whether such errors are within predetermined tolerance limits;

said plurality of nozzles being automatically controlled to compensate for those errors within a pretermined tolerance limit;

the operation of said printer being automatically terminated upon detection of an error exceeding said pretermined tolerance limits.

17. The method according to claim 16, wherein said printing parameter errors detected include phase errors caused by incorrect timing of the charging of said drops with the formation of said drops in a nozzle; said phase errors being automatically compensated for by controlling the timing of the charging pulses applied to said drops in the respective nozzle.

18. The method according to claim 17, wherein said printing parameter errors detected include velocity errors caused by incorrect velocity of the drops emitted by a nozzle; said velocity errors being automatically

compensated for by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

19. The method according to claim 18, wherein said printing parameter errors to be detected further include:

X-axis offset errors caused by incorrect alignment of a nozzle with respect to the X-axis, which X-axis offset errors are automatically compensated for by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

20. The method according to claim 19, wherein said printing parameter errors to be detected further include:

Y-axis errors caused by incorrect alignment of a nozzle with respect to the Y-axis, which Y-axis errors are automatically compensated for by restructuring the timing of the printing data.

21. The method according to claim 20, wherein said printing parameter errors to be detected further include:

angular offset errors caused by asymmetry of the electrical field between the deflection plates associated with a nozzle, which angular-offset errors are automatically compensated for by restructuring the printing data.

22. The method according to claim 21, wherein said printing parameter errors are detected by performing a series of test operations, including:

(a) effecting relative movement between the print head and the test strip along the Y-axis;

(b) sequentially applying multi-level charging pulses to each nozzle to produce printed marks defining an X-line segment for each nozzle along the deflection direction (X-axis); and

(c) sequentially scanning from 0° through 360° the phase of the charging pulses applied to each nozzle at each of a first and a second charge level to produce two printed parallel lines of marks for each nozzle along the scanning direction (Y-axis);

said two printed parallel lines along the scanning direction (Y-axis) produced during operation (c) being straight and unbroken in the absence of a phase error, and being broken, fuzzy or non-linear at the phase where a phase error occurs, thereby indicating the presence of a phase error and the phase at which such error occurs;

the spacing in the deflection direction between said two printed parallel lines produced during operation (c) indicating the presence and magnitude of a velocity error;

the lateral amount in the deflection direction by which the line of marks printed at said first charge level of each nozzle during operation (c) deviates from the nominal position of the nozzle, indicating the presence and magnitude of an X-axis offset error;

the spatial amount in the scanning direction by which the raster line generated by each nozzle during operation (c) deviates from the "mean" raster line for all nozzles, indicating the presence and magnitude of a Y-axis offset error; and

the angular amount by which said X-line segments printed during operation (b) deviates with respect to the deflection direction, indicating the presence and magnitude of an angular offset error.

23. A method of testing the operation of a nozzle in an ink-jet printer emitting, towards a substrate, a series of ink drops broken-off from a continuous ink jet filament while effecting relative movement between the nozzle and the substrate in a scanning direction (the Y-axis), and while selectively charging the drops with multi-level charging pulses and then deflecting

the drop in the deflection direction (the X-axis) according to the pattern of marks to be printed by the nozzle on the substrate, comprising:

sequentially scanning from 0° through 360° the phase of the charging pulses applied to the nozzle at least at one charge level to produce a printed line of marks along the scanning direction (Y-axis);

and determining whether said printed line is straight and unbroken, indicating the absence of a phase error, or is broken, fuzzy or non-linear, indicating the presence of a phase error and the phase where the error occurs.

24. The method according to claim 23, wherein two parallel lines are printed at two charge levels, the spacing in the deflection direction is measured between said two printed parallel lines to indicate the presence and magnitude of a velocity error..

25. Ink jet printing apparatus, comprising:

a print head having a plurality of nozzles each for emitting a series of ink drops towards a substrate while relative movement is effected between the print head and the substrate;

an electrical charger and an electrical deflector for selectively charging and deflecting said drops according to a pattern of marks to be printed on the substrate;

a processor programmed to control said print head and said electrical charger to cause the nozzles to emit ink drops, and the charger to charge the ink drops, according to the pattern to be printed on the substrate;

said processor also being programmed to control said plurality of nozzles to print a pattern of test marks for each nozzle on a test strip;

and a sensor for sensing said pattern of test marks for each nozzle and for producing output signals corresponding to said patterns of test marks.

26. The apparatus according to claim 25, wherein said processor is further programmed:

to analyze said sensor-output signals corresponding to said patterns of test marks with respect to a number of printing parameters:

to detect errors in said printing parameters and to determine whether such errors are within predetermined tolerance limits;

to automatically control said plurality of nozzles to compensate for those errors within said predetermined tolerance limits; and

to automatically terminate the operation of said printer upon the detection of an error exceeding a predetermined tolerance limit.

27. The apparatus according to claim 26, wherein said sensor is an optical sensor and is coupled to said print head to move therewith.

28. The apparatus according to claim 26, wherein said printing parameter errors to be detected include phase errors caused by incorrect timing of the charging of said drops with the formation of said drops in a nozzle; said processor automatically compensating for said phase errors by controlling the timing of the charging pulses applied to said drops in the respective nozzle.

29. The apparatus according to claim 28, wherein said printing parameter errors to be detected include velocity errors caused by incorrect velocity of the drops emitted by a nozzle; said processor automatically compensating for said velocity errors by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

30. The apparatus according to claim 29, wherein said printing parameter errors to be detected include X-axis offset errors caused by incorrect alignment of a nozzle with respect to the x-axis; said processor automatically compensating for said x-axis offset errors by controlling the magnitude of the charging pulses applied to said drops in the respective nozzle.

31. The apparatus according to claim 30, wherein said printing parameter errors to be detected further include Y-axis offset errors caused by incorrect alignment of a nozzle with respect to the Y-axis; said processor automatically compensating for said Y-axis offset errors by restructuring the timing of the printing.

32. The apparatus according to claim 31, wherein said printing parameter errors to be detected further include angular offset errors caused by asymmetry of the electrical field between the deflection plates associated with a nozzle; said processor automatically compensating for said angular-offset errors by restructuring the printing data.

33. The apparatus according to claim 32, wherein said processor is programmed to detect said printing parameter errors by performing a series of test operations, including:

(a) effecting relative movement between the print head and the test strip along the Y-axis;

(b) sequentially applying multi-level charging pulses to each nozzle to produce printed marks defining an X-line segment for each nozzle along the deflection direction (X-axis); and

(c) sequentially scanning from 0° through 360° the phase of the charging pulses applied to each nozzle at each of a first and a second charge level to produce two printed parallel lines of marks for each nozzle along the scanning direction (Y-axis);

said two printed parallel lines along the scanning direction (Y-axis) produced during operation (c) being straight and unbroken in the absence of a phase error, and being broken, fuzzy or non-linear at the phase where a phase error occurs, thereby indicating the presence of a phase error and the phase at which such error occurs;

the spacing in the deflection direction between said two printed parallel lines produced during operation (c) indicating the presence and magnitude of a velocity error;

the lateral amount in the deflection direction by which the line of marks printed at said first charge level of each nozzle during operation (c) deviates from the nominal position of the nozzle, indicating the presence and magnitude of an X-axis offset error;

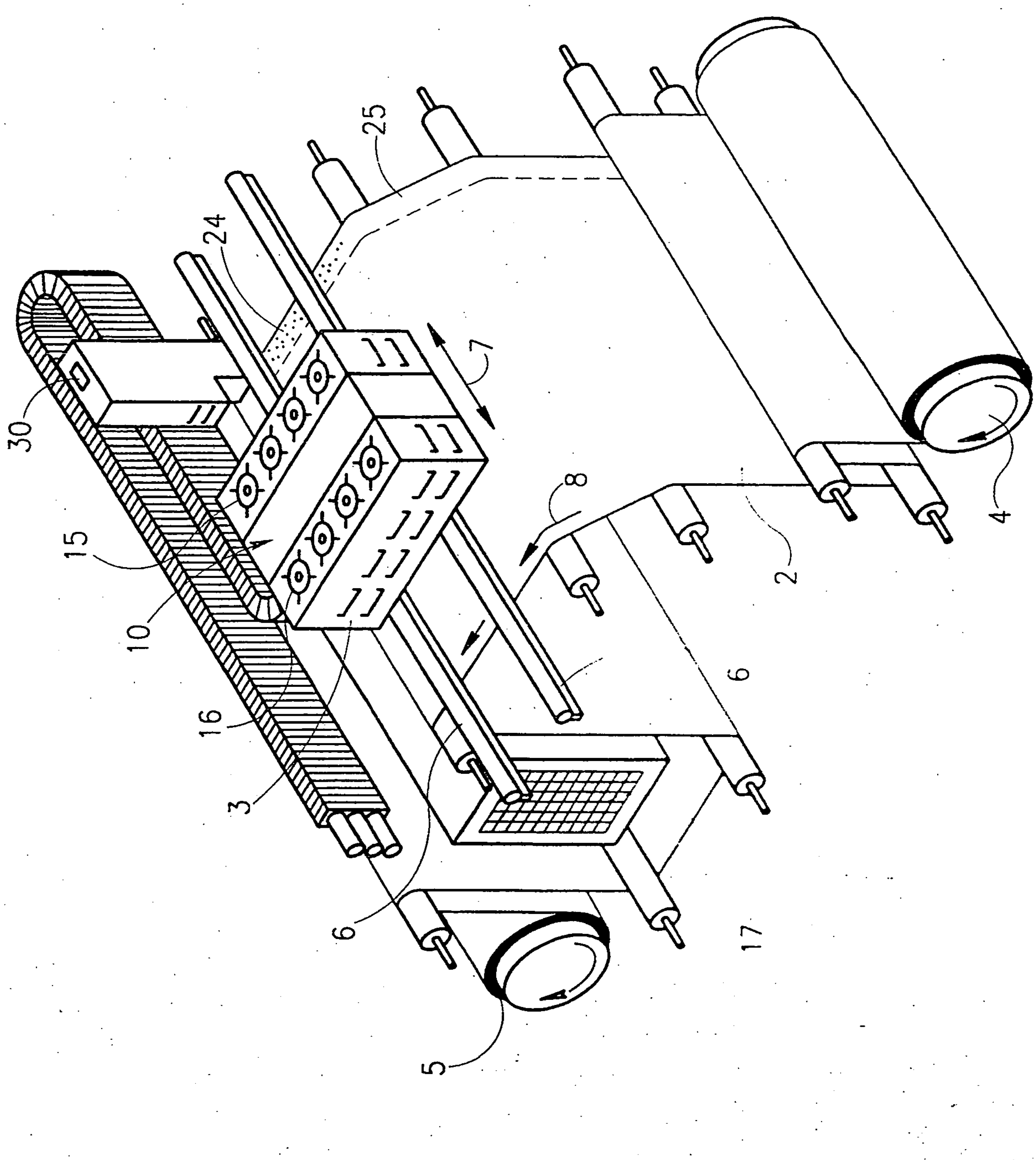
the spatial amount in the scanning direction by which the raster line generated by each nozzle during operation (c) deviates from the "mean" raster line for all nozzles, indicating the presence and magnitude of a Y-axis offset error; and

the angular amount by which said X-line segments printed during operation (b) deviates with respect to the deflection direction, indicating the presence and magnitude of an angular offset error.

34. The apparatus according to claim 25, wherein said apparatus further includes a print head drive which continuously drives said print head transversely across said substrate, and a substrate drive which drives said substrate in steps longitudinally of said substrate.

35. The apparatus according to claim 34, wherein said apparatus is a multi-color printer and includes a plurality of monochrome print heads of different colors assembled together longitudinally of said substrate.

FIG.1



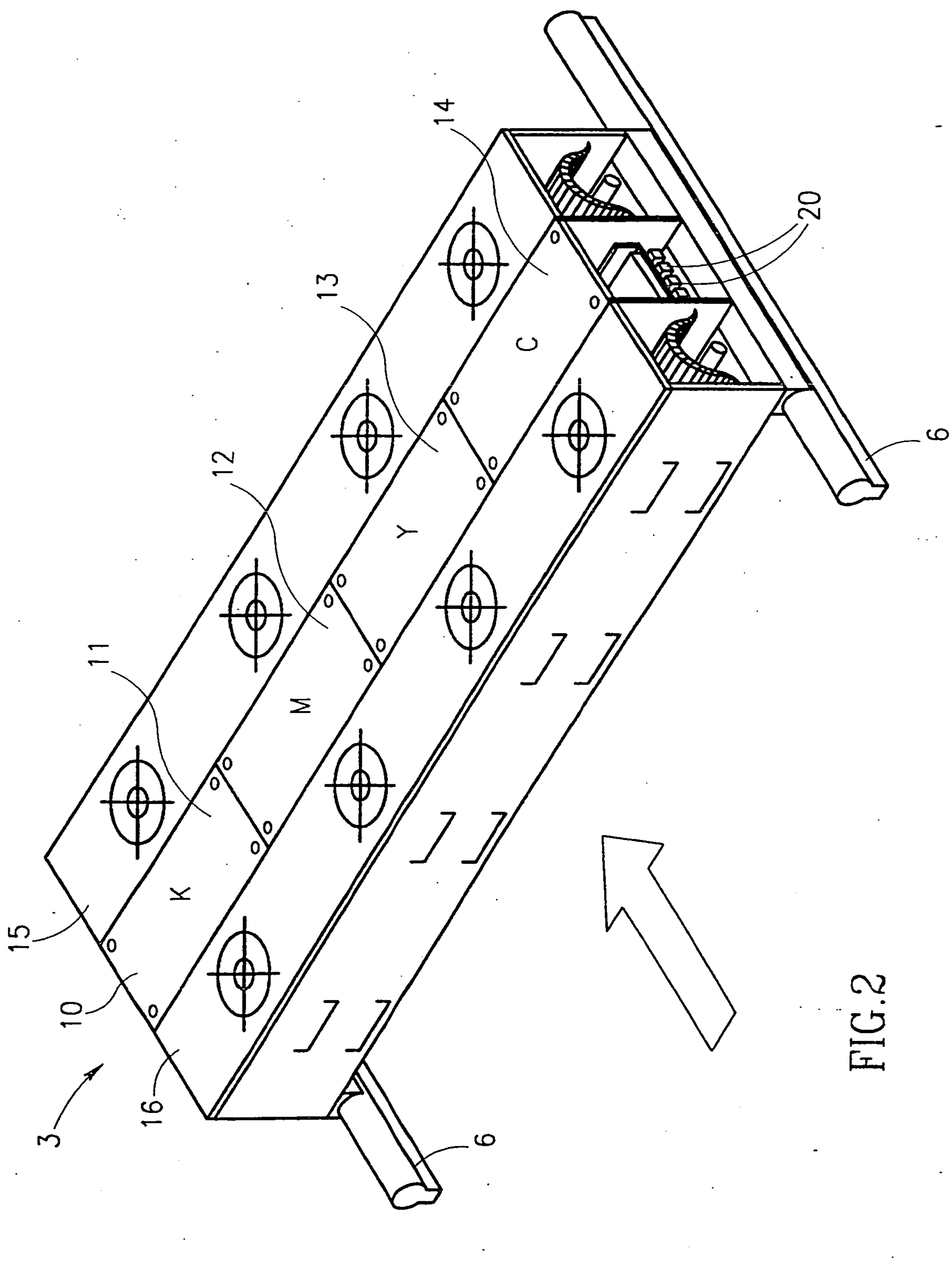


FIG.2

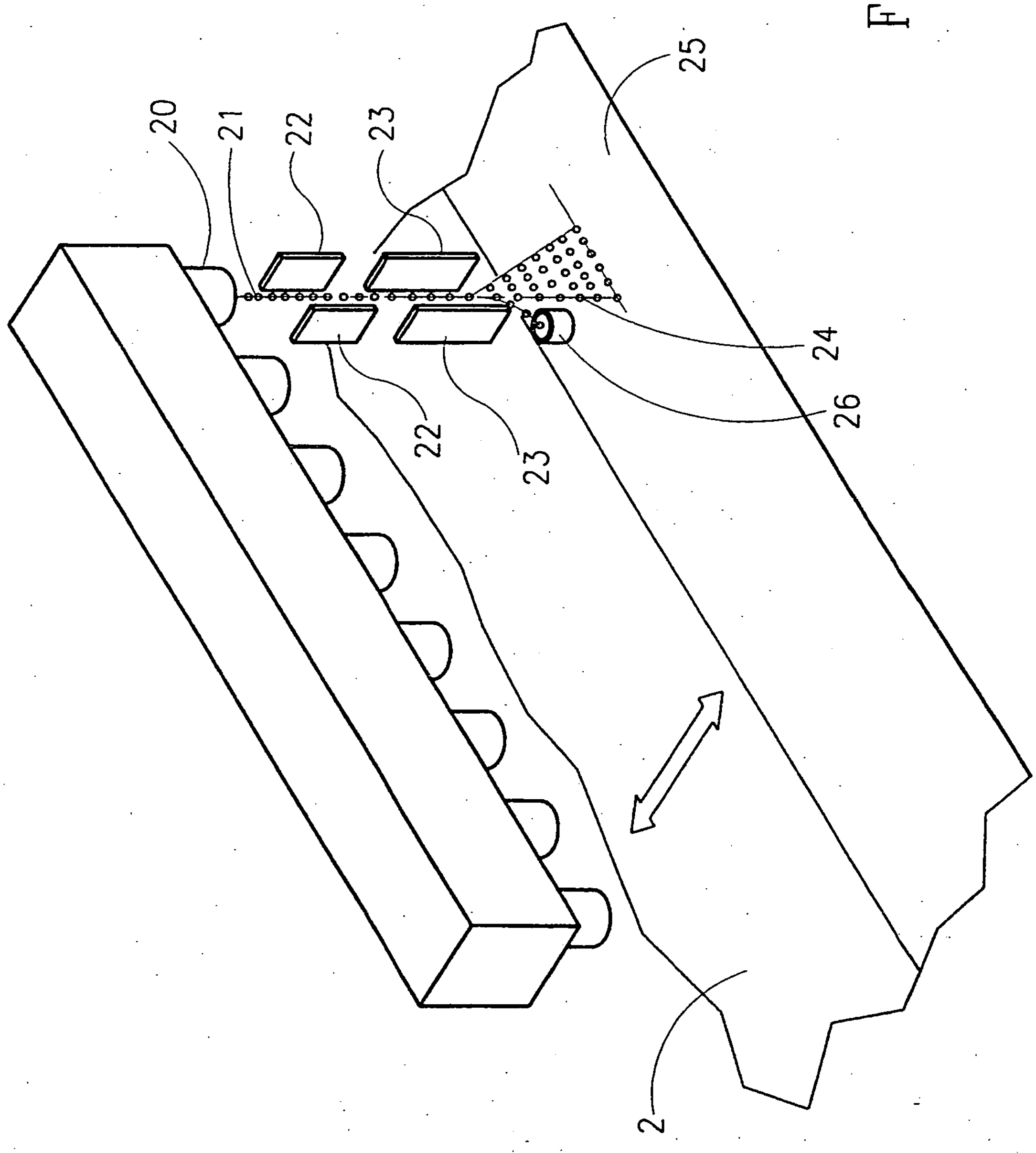


FIG.3

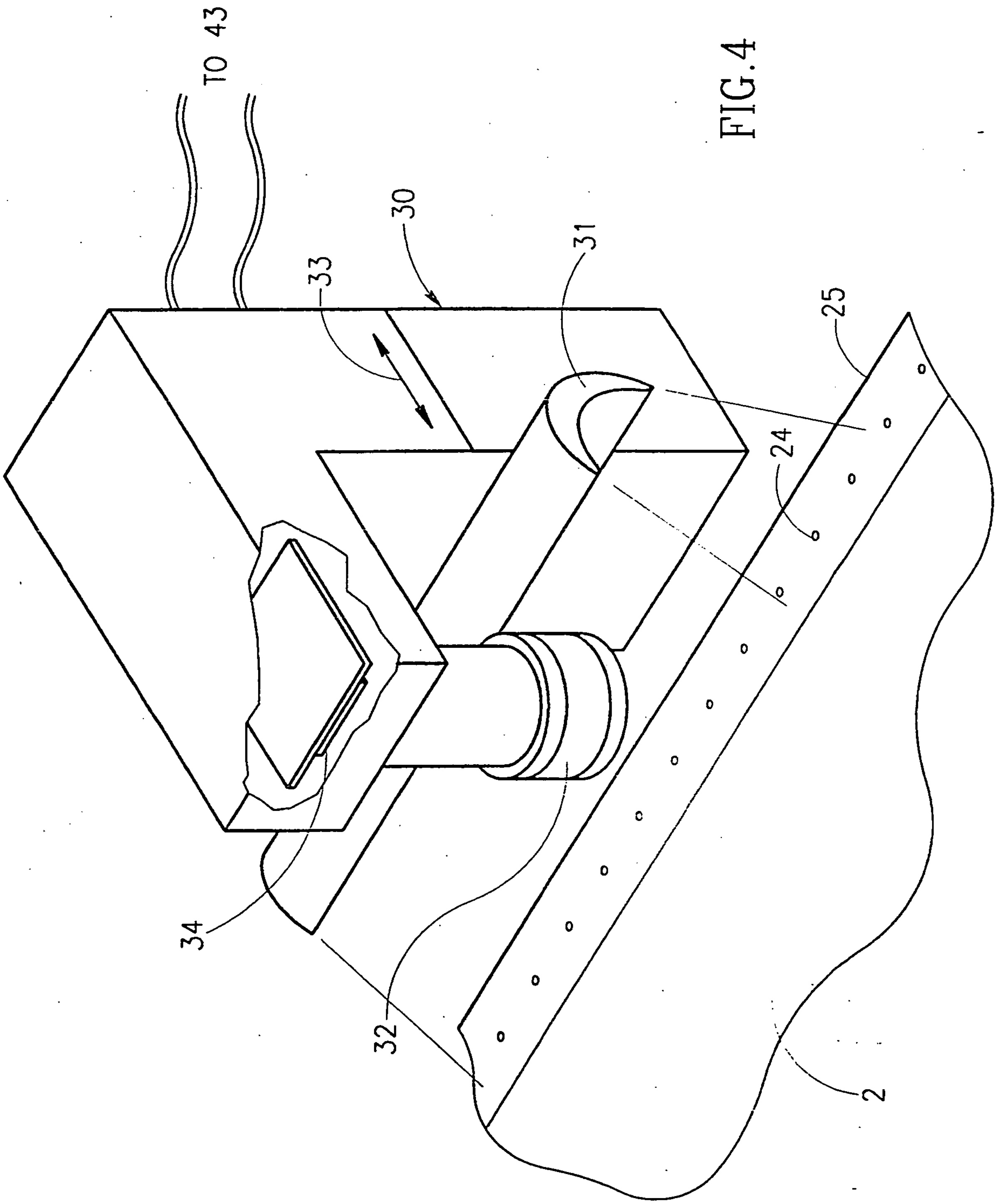


FIG.4

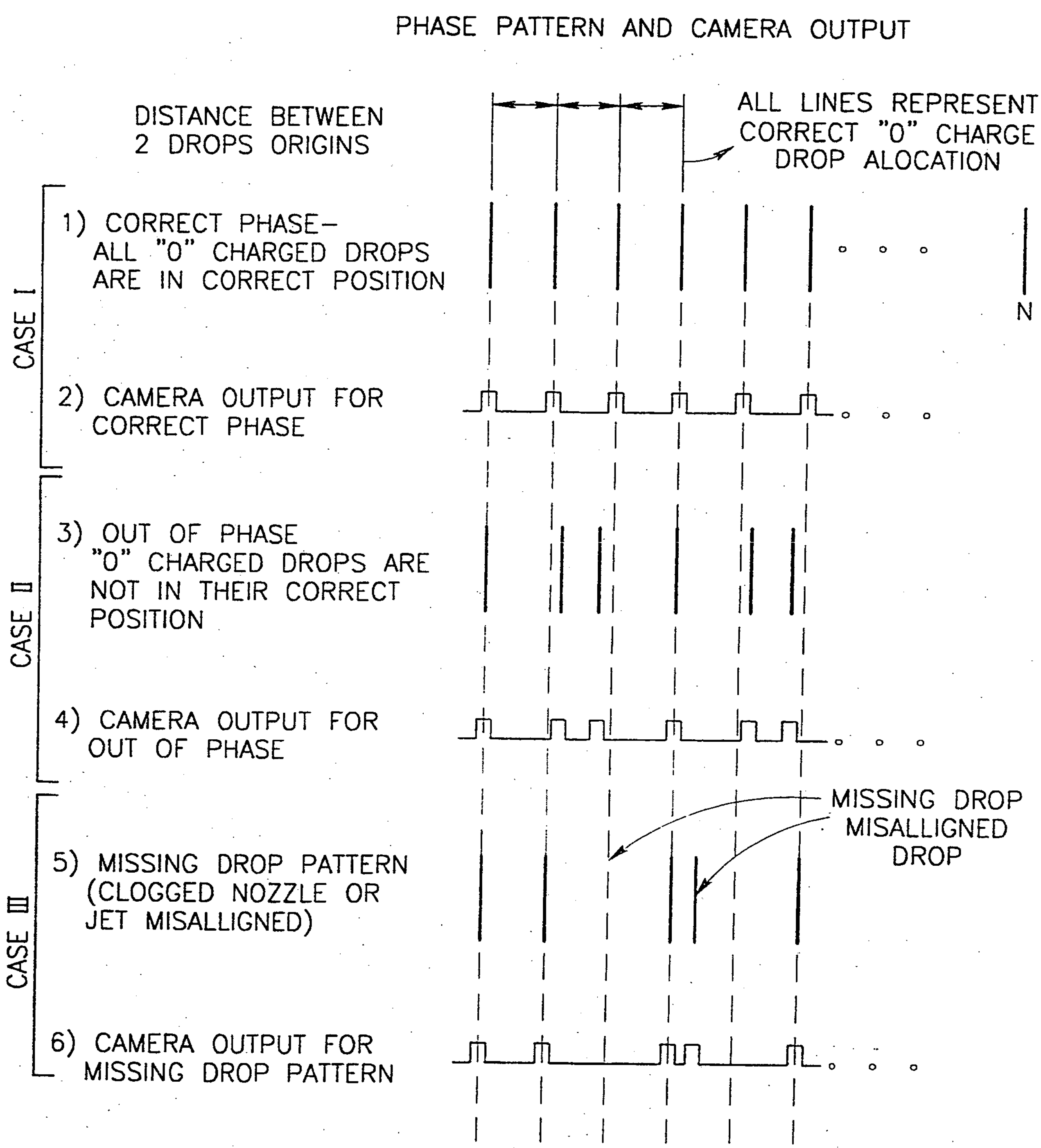

PHASE PATTERN AND CAMERA OUTPUT
DISTANCE BETWEEN 2 DROPS ORIGINS
ALL LINES REPRESENT CORRECT "0" CHARGE DROP ALOCATION
CASE I
1) CORRECT PHASE– ALL "0" CHARGED DROPS ARE IN CORRECT POSITION
N
2) CAMERA OUTPUT FOR CORRECT PHASE
CASE II
3) OUT OF PHASE "0" CHARGED DROPS ARE NOT IN THEIR CORRECT POSITION
4) CAMERA OUTPUT FOR OUT OF PHASE
CASE III
MISSING DROP
MISALLIGNED DROP
5) MISSING DROP PATTERN (CLOGGED NOZZLE OR JET MISALLIGNED)
6) CAMERA OUTPUT FOR MISSING DROP PATTERN

FIG.5

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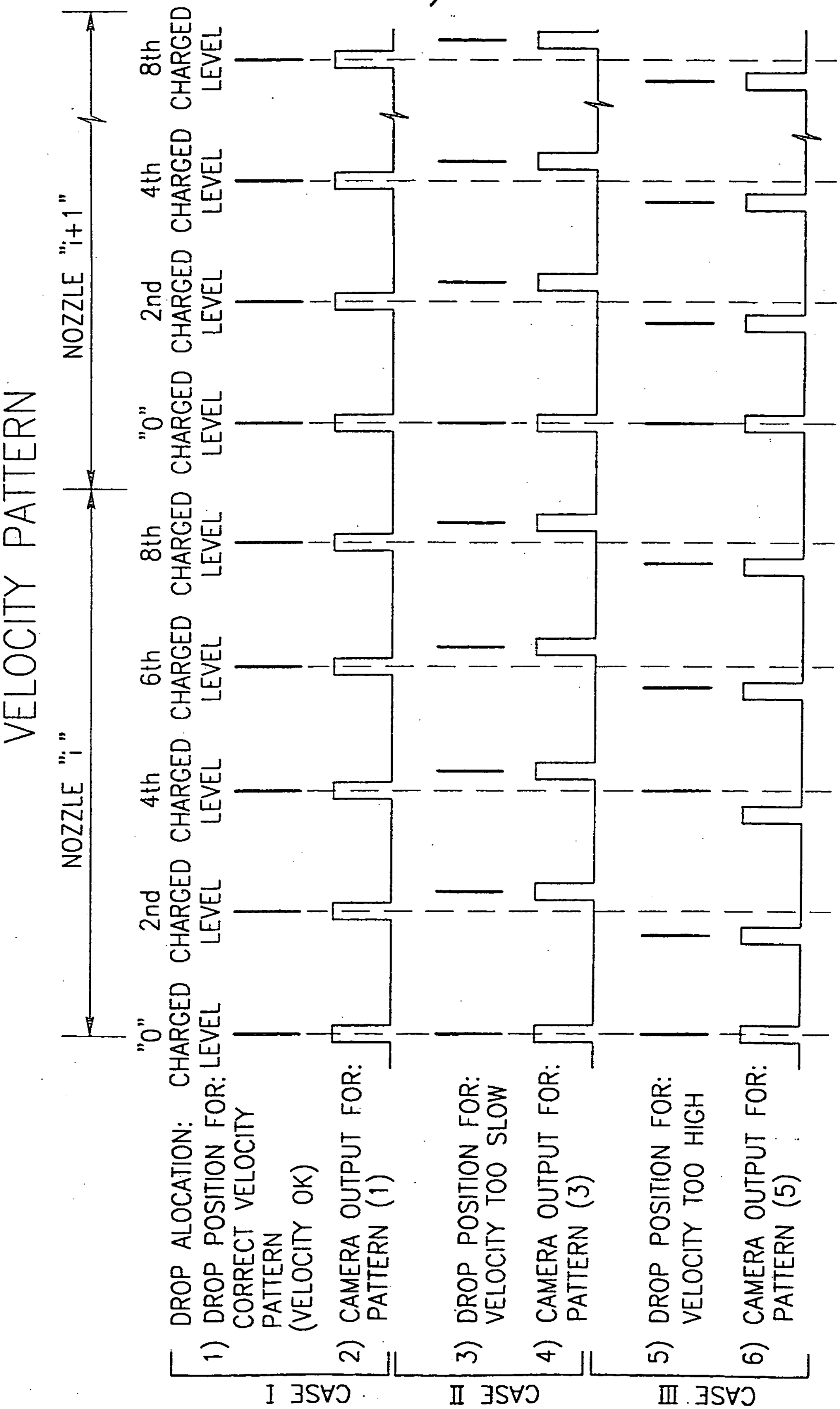

VELOCITY PATTERN
NOZZLE "i"
NOZZLE "i+1"
DROP ALOCATION:
"0" CHARGED LEVEL
2nd CHARGED LEVEL
4th CHARGED LEVEL
6th CHARGED LEVEL
8th CHARGED LEVEL
"0" CHARGED LEVEL
2nd CHARGED LEVEL
4th CHARGED LEVEL
8th CHARGED LEVEL
CASE I
1) DROP POSITION FOR: CORRECT VELOCITY PATTERN (VELOCITY OK)
2) CAMERA OUTPUT FOR: PATTERN (1)
CASE II
3) DROP POSITION FOR: VELOCITY TOO SLOW
4) CAMERA OUTPUT FOR: PATTERN (3)
CASE III
5) DROP POSITION FOR: VELOCITY TOO HIGH
6) CAMERA OUTPUT FOR: PATTERN (5)

FIG.6

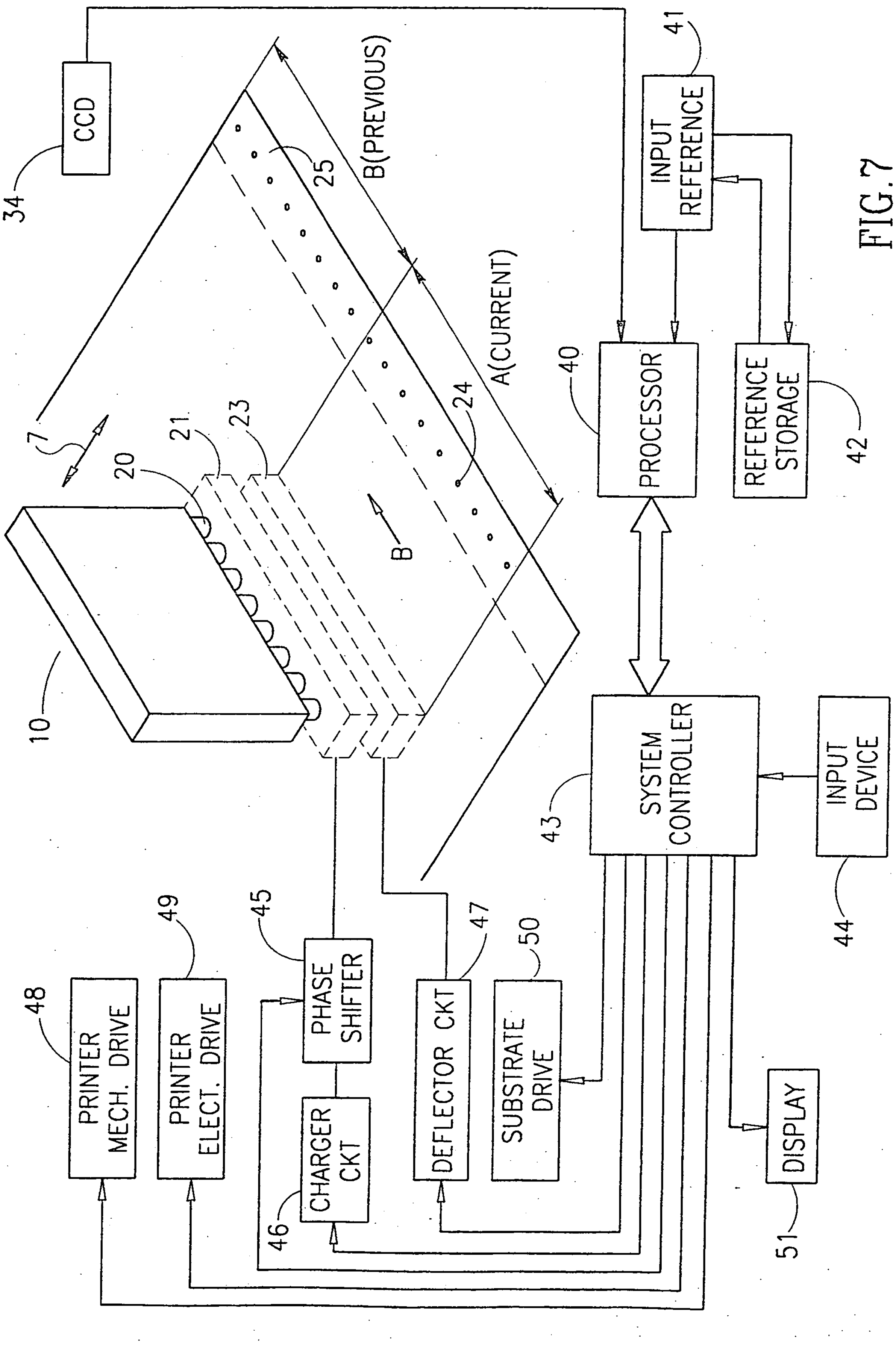

CCD
34
7
10
20
21
23
25
24
B(PREVIOUS)
A(CURRENT)
B
INPUT REFERENCE
41
PROCESSOR
40
REFERENCE STORAGE
42
SYSTEM CONTROLLER
43
INPUT DEVICE
44
PHASE SHIFTER
45
CHARGER CKT
46
DEFLECTOR CKT
47
PRINTER MECH. DRIVE
48
PRINTER ELECT. DRIVE
49
SUBSTRATE DRIVE
50
DISPLAY
51

FIG.7

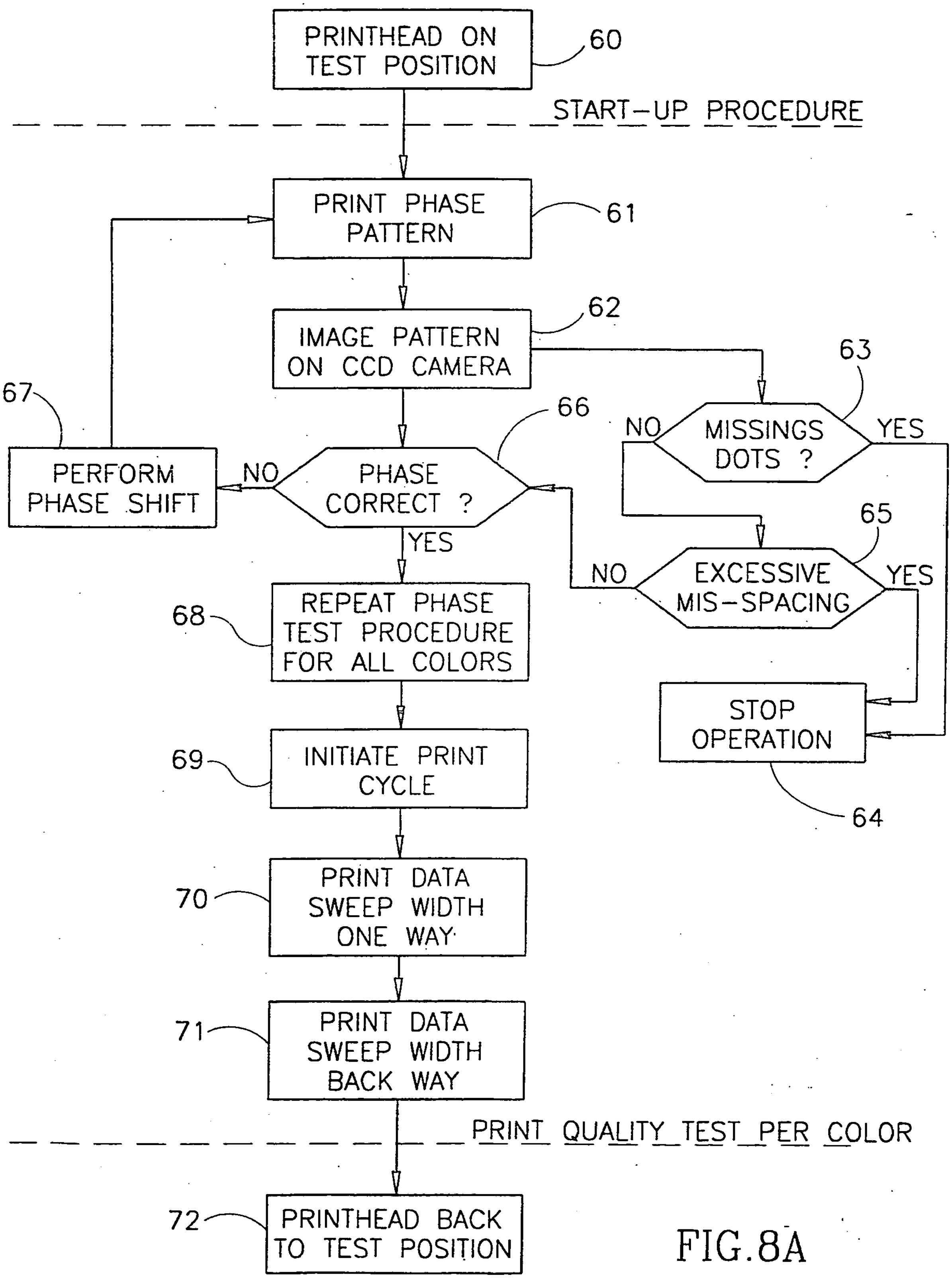

PRINTHEAD ON TEST POSITION
60
START-UP PROCEDURE
PRINT PHASE PATTERN
61
IMAGE PATTERN ON CCD CAMERA
62
63
MISSINGS DOTS ?
NO
YES
67
PERFORM PHASE SHIFT
NO
PHASE CORRECT ?
66
YES
65
EXCESSIVE MIS-SPACING
NO
YES
68
REPEAT PHASE TEST PROCEDURE FOR ALL COLORS
STOP OPERATION
64
69
INITIATE PRINT CYCLE
70
PRINT DATA SWEEP WIDTH ONE WAY
71
PRINT DATA SWEEP WIDTH BACK WAY
PRINT QUALITY TEST PER COLOR
72
PRINTHEAD BACK TO TEST POSITION

FIG.8A

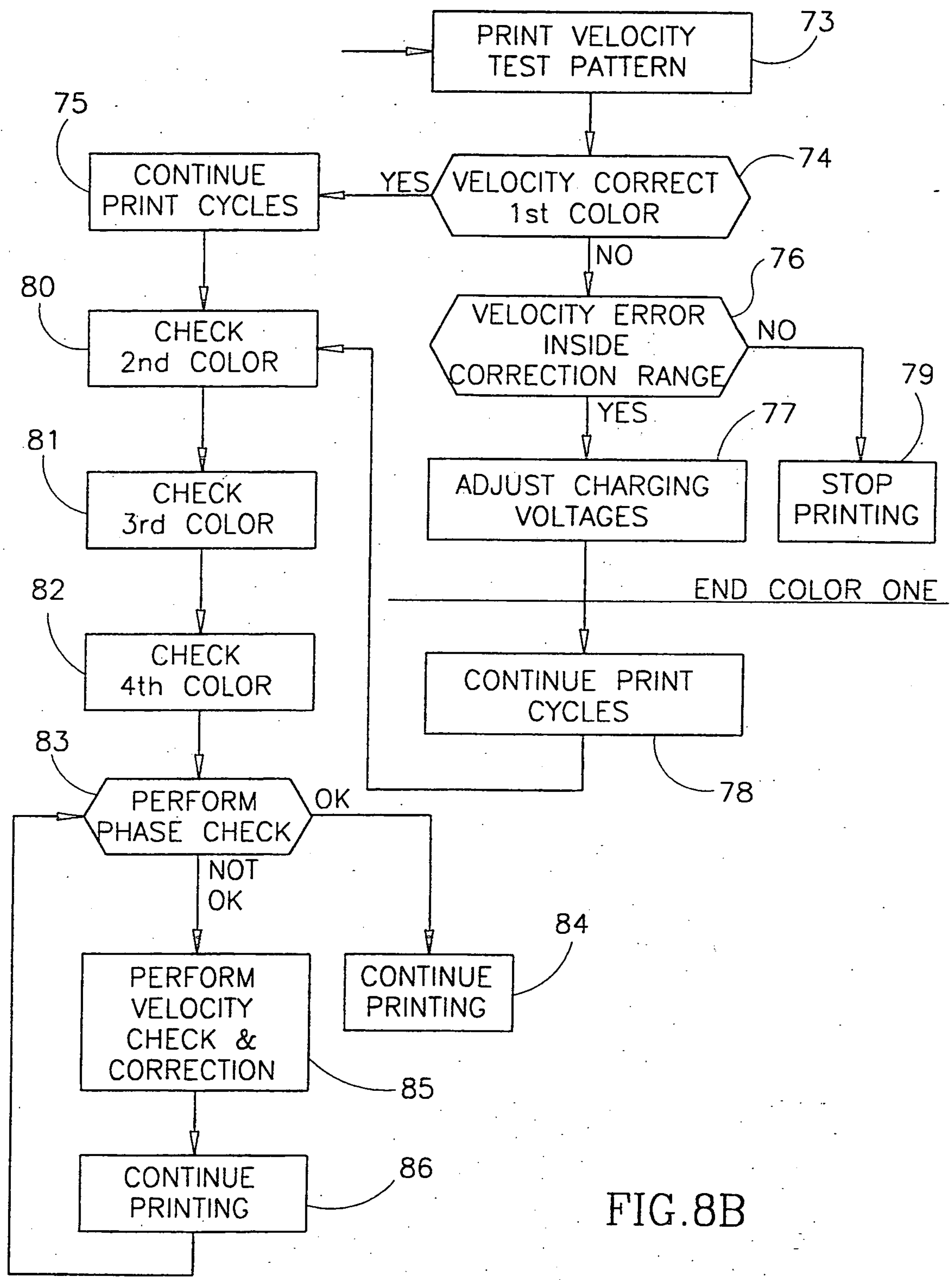

PRINT VELOCITY TEST PATTERN
73
VELOCITY CORRECT 1st COLOR
74
YES
NO
CONTINUE PRINT CYCLES
75
VELOCITY ERROR INSIDE CORRECTION RANGE
76
NO
YES
ADJUST CHARGING VOLTAGES
77
STOP PRINTING
79
END COLOR ONE
CONTINUE PRINT CYCLES
78
CHECK 2nd COLOR
80
CHECK 3rd COLOR
81
CHECK 4th COLOR
82
PERFORM PHASE CHECK
83
OK
NOT OK
CONTINUE PRINTING
84
PERFORM VELOCITY CHECK & CORRECTION
85
CONTINUE PRINTING
86

FIG.8B

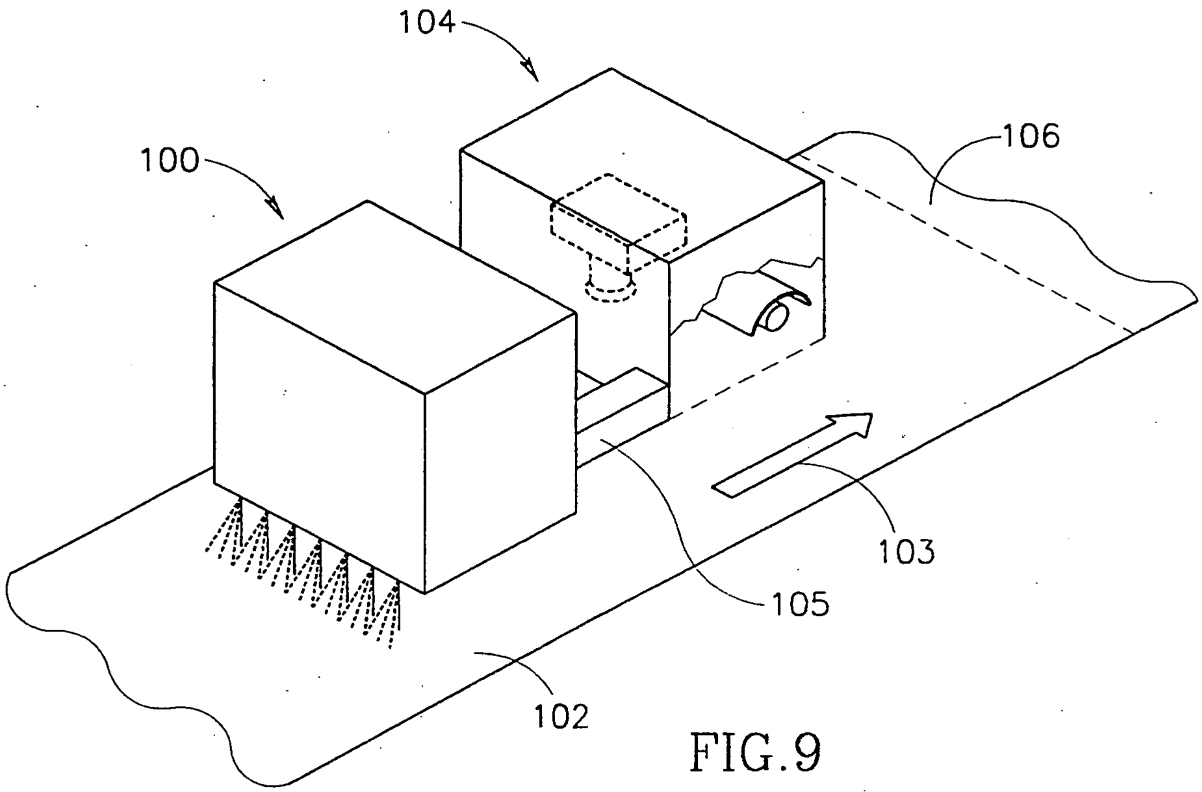


FIG.9

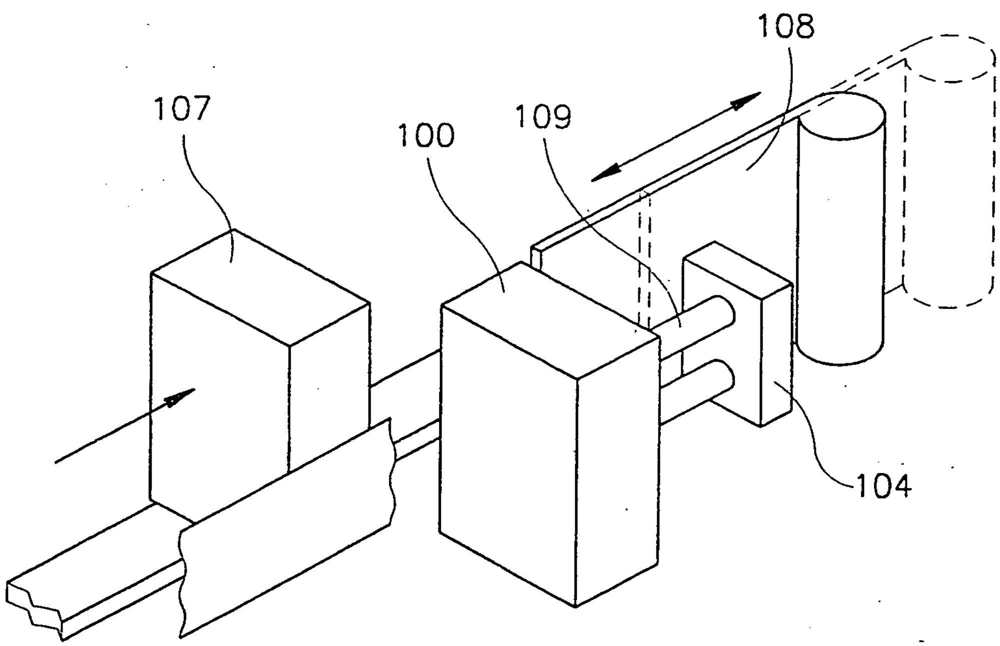


FIG.10

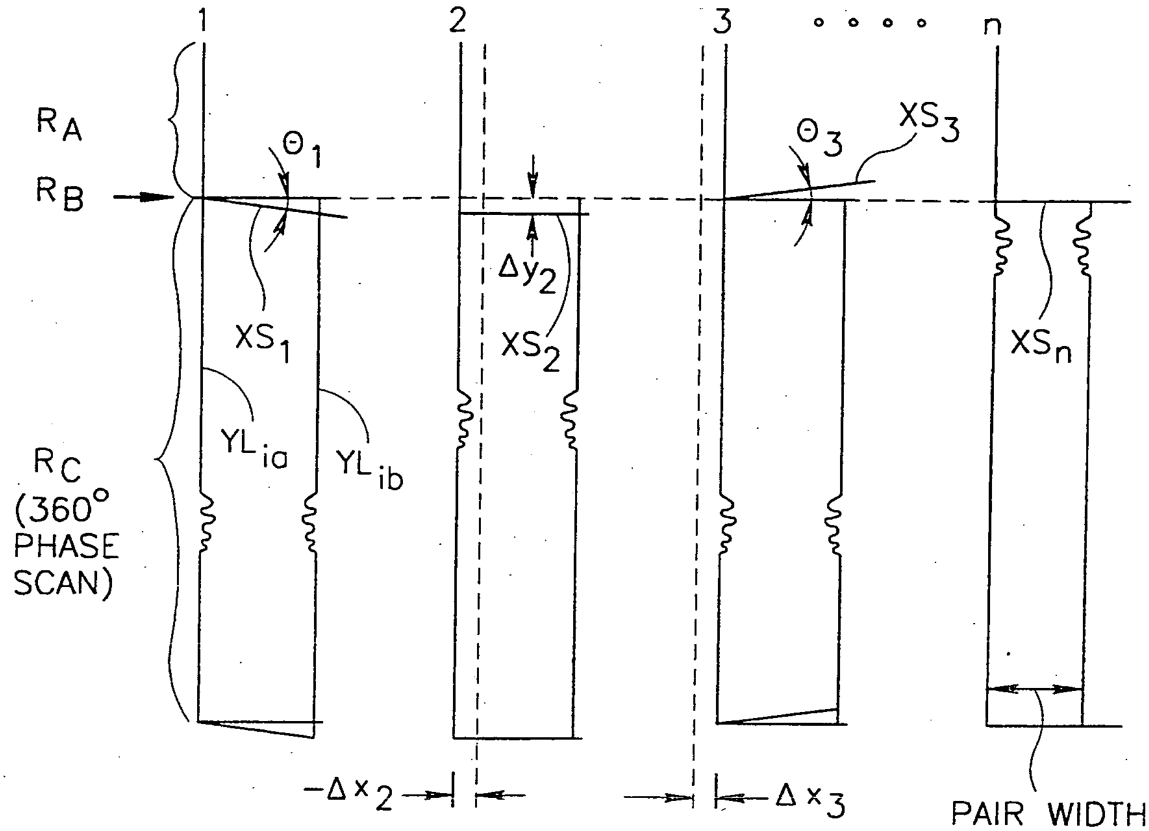

1
2
3
n
R_A
R_B
Θ_1
Θ_3
XS_3
Δy_2
XS_1
XS_2
XS_n
YL_{ia}
YL_{ib}
R_C
(360°
PHASE
SCAN)
$-\Delta x_2$
Δx_3
PAIR WIDTH

FIG.11

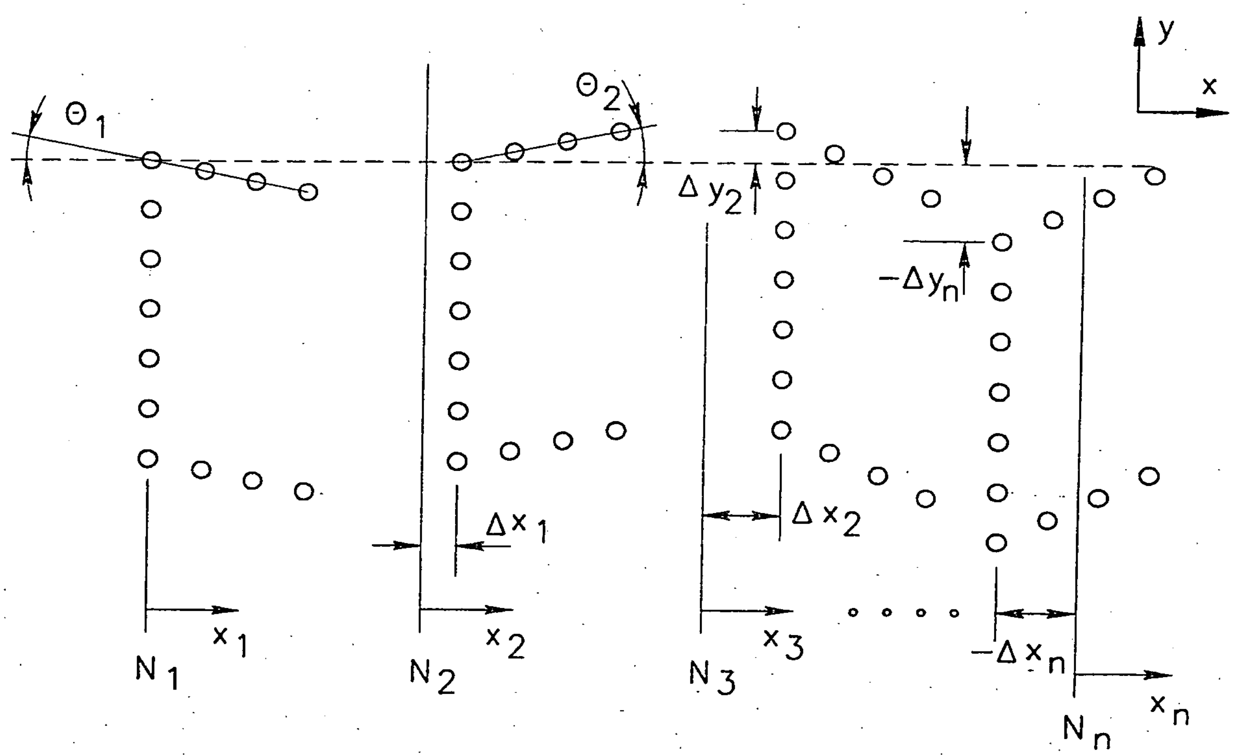
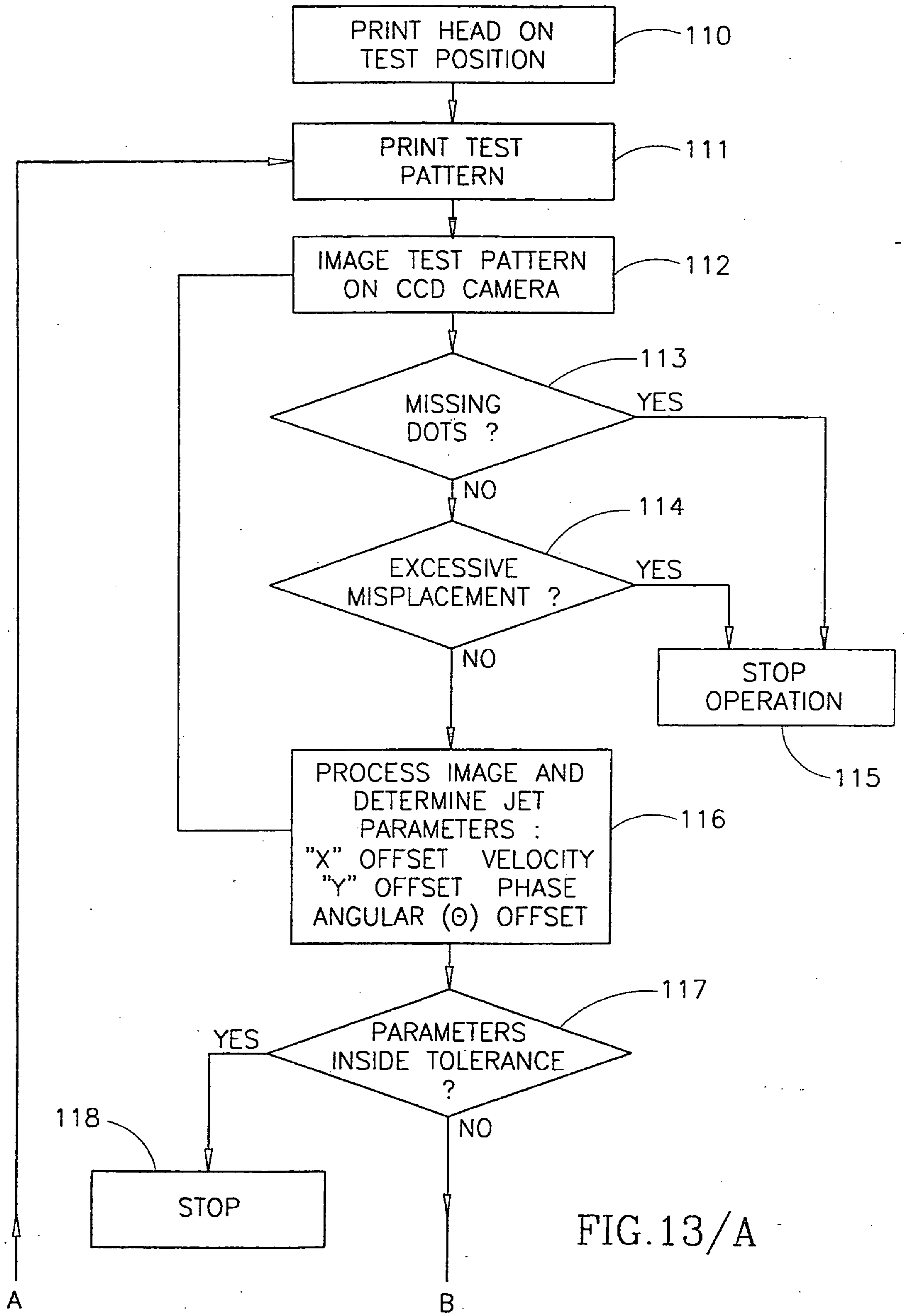

y
x
Θ_1
Θ_2
Δy_2
$-\Delta y_n$
Δx_1
Δx_2
$-\Delta x_n$
x_1
x_2
x_3
x_n
N_1
N_2
N_3
N_n

FIG.12



PRINT HEAD ON TEST POSITION
110
PRINT TEST PATTERN
111
IMAGE TEST PATTERN ON CCD CAMERA
112
113
MISSING DOTS ?
YES
NO
114
EXCESSIVE MISPLACEMENT ?
YES
NO
STOP OPERATION
115
PROCESS IMAGE AND DETERMINE JET PARAMETERS :
"X" OFFSET VELOCITY
"Y" OFFSET PHASE
ANGULAR (Θ) OFFSET
116
117
PARAMETERS INSIDE TOLERANCE ?
YES
NO
118
STOP
A
B

FIG.13/A

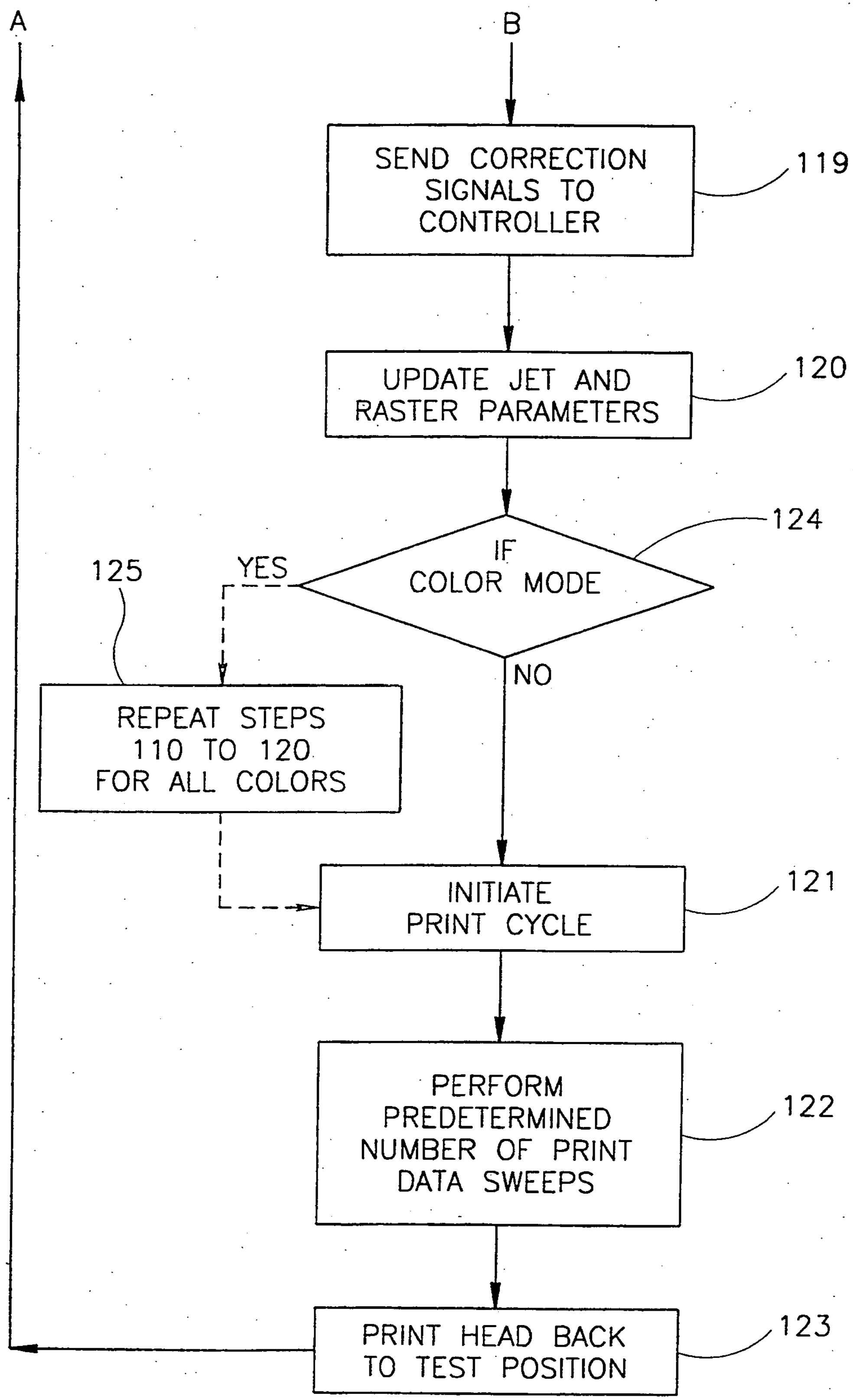

A
B
SEND CORRECTION SIGNALS TO CONTROLLER
119
UPDATE JET AND RASTER PARAMETERS
120
IF COLOR MODE
124
YES
125
REPEAT STEPS 110 TO 120 FOR ALL COLORS
NO
INITIATE PRINT CYCLE
121
PERFORM PREDETERMINED NUMBER OF PRINT DATA SWEEPS
122
PRINT HEAD BACK TO TEST POSITION
123

FIG.13/B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00143

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B41J 2/12, 29/393, 2/125
US CL : 347/19, 347/78, 347/81
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 347/19, 347/78, 347/81

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

n/a

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 4,907,013 (Hubbard et al.) 06 March 1990 (06.03.90), col. 5, lines 26-30; col 4, lines 49-55; col 2, lines 8-40; col 6, lines 7-60; col 8, lines 18-68.	1-6 ---------------- 15-22, 29-31
Y	US 4,542,385 (Jinnai et al.) 17 September 1985 (17.09.85), see figures 4-6, and entire document.	15-22
Y	US 5,189,521 (Ohtsubo et al.) 23 Feb 1993 (23.02.93), see figures 2-3.	29-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 JUNE 1998	24 JUL 1998

Name and mailing address of the ISA/US	Authorized officer
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Facsimile No. (703) 305-3230	Telephone No. (703) 308-0080

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS

Search terms: continuous ink jet, velocity error, optical sensor, ccd, misalign, phase shifter, charger, deflector